# Acoustic Clutter in Continental Shelf Environments


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## LONG-TERM GOALS

Acoustic clutter is the primary problem encountered by active sonar systems operating in Continental Shelf environments. Clutter is defined as any returns from the environment that stand prominently above the diffuse and temporally decaying reverberation background and so can be confused with or camouflage returns from an intended target such as an underwater vehicle. The long-term goal of this program is to determine and understand the physical mechanisms that cause acoustic clutter in continental shelf environments with little or no bathymetric relief and to use this knowledge to develop predictive tools to enhance the detection, localization and classification of underwater targets.

## OBJECTIVES

The primary objectives of this program are to:

- Characterize the spatial and temporal variability of clutter in continental shelf environments with little or no bathymetric relief.
- Determine the primary causes of clutter in continental shelf environments with little or no bathymetric relief.
- Develop unified physical models for reverberation and scattering from objects submerged in an ocean waveguide and compare them with experimental data.

## APPROACH

The approach is to combine the analysis of experimental data with full-field waveguide modeling of clutter, acoustic reverberation, and target scattering. Under the Acoustic Clutter Program, formerly the Geologic Clutter Program, the Acoustic Clutter Reconnaissance Experiment (ARE) 2001 was primarily aimed at just establishing the presence and persistence of acoustic clutter off the New Jersey continental shelf. This year's Main Acoustics Experiment (MAE), instead, was designed to be very controlled, so that the actual mechanisms for the clutter could be established. It also had precise calibration so that theories and models could be accurately tested. Full-field waveguide scattering models, simulations and statistical studies helped direct experiment design and support the analysis and interpretation of experiment results.

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14. ABSTRACT
**Acoustic clutter is the primary problem encountered by active sonar systems operating in Continental Shelf environments. Clutter is defined as any returns from the environment that stand prominently above the diffuse and temporally decaying reverberation background and so can be confused with or camouflage returns from an intended target such as an underwater vehicle. The long-term goal of this program is to determine and understand the physical mechanisms that cause acoustic clutter in continental shelf environments with little or no bathymetric relief and to use this knowledge to develop predictive tools to enhance the detection, localization and classification of underwater targets.**

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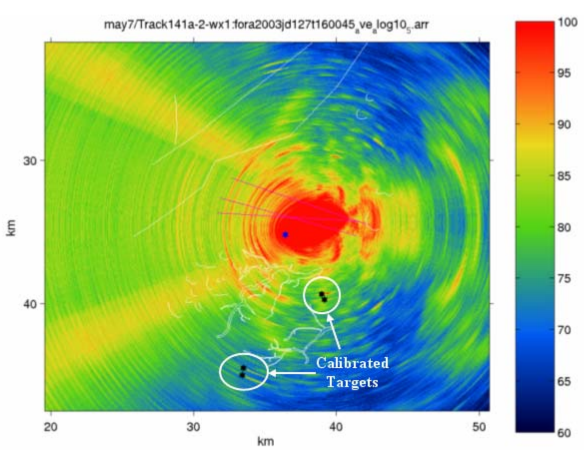
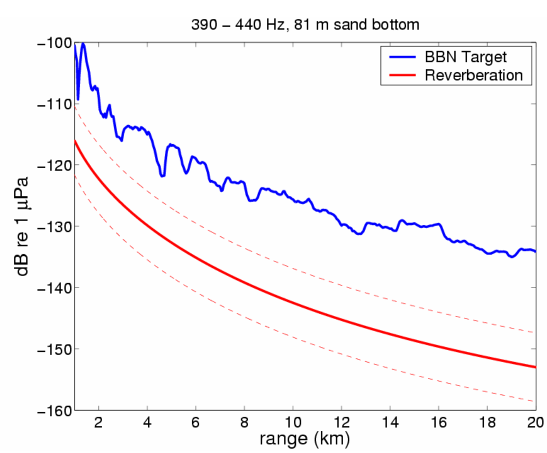
## WORK COMPLETED / RESULTS

MAE 2003 of the Geoclutter Program, conducted from April 28 to May 24, was a great success in demonstrating that discrete clutter events are consistently a major problem for active sonar operations in Continental Shelf environments, even those with little or no bathymetric relief. It was also a great success in determining the most likely physical mechanism for this clutter.

In MAE 2003, three ships were used. One ship, the UNOL Endeavor, was moored at a number of locations where the MACE sources, XF4 and Mod 30 arrays, were deployed. Another, the UNOL Oceanus, was used to tow the newly made ONR Five Octave Research Array as a receiver to bistatically probe for clutter over ranges extending to roughly 40 km in the low to mid frequency range from roughly 400 to 1500 Hz. The third ship, the UNOL Cape Henlopen, was used to probe for highly concentrated fish schools using downward directed SIMRAD fish finding sonar and to determine whether these schools occur in the location of clutter events at the same time the clutter events are measured.

In order to demonstrate the prevalence of clutter, on the order of 5000 waveforms or "pings" were transmitted into the water column and roughly 10 to 100 discrete clutter events per ping were received, giving a total of at least 50,000 clutter events that could be confused with a discrete target over the period of the experiment. This is consistent with our findings from the ARE of 2001. In fact, between 2 to 5 discrete calibrated targets (BBN Reflectors and a special bottom mounted target) with known scattering properties were deployed at various times throughout the experiment. Without apriori knowledge of the targets' locations, these targets would have been consistently indistinguishable from clutter arising from natural environmental scatterers (lower left figure). A unified model for full-field scattering from submerged objects and reverberation in an ocean waveguide [5], developed by the PI in this program, correctly estimated scattering from the BBN target to stand roughly 10-20 dB above the diffuse reverberation level. This simulation is shown in the lower right figure, which compares monostatic scattering level from a BBN target (blue) with reverberation level (red). This analysis used an 81-m Pekeris sand bottom environment, and a 390-440 Hz broadband source. Dotted red lines represent 5.6 dB standard deviation of the diffuse reverberation.



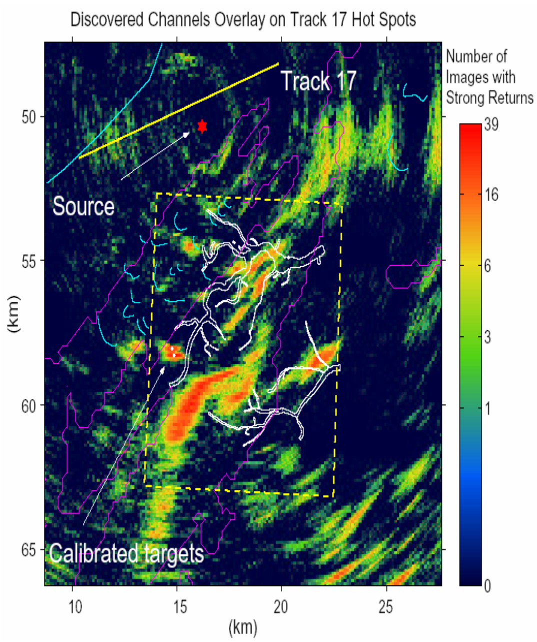

Three key findings of ARE 2001 influenced the design of MAE 2003 [1]:
(1) In ARE 2001, it was found that many clutter returns appeared to register with known geologic features, but many prominent and target-like returns also occurred in regions where the sub-bottom had not been surveyed for geologic features. Subsequent geologic surveys of these previously unexplored

regions indicated that some of the corresponding unidentified clutter features now registered with newly-discovered sub-bottom features such as buried river channels, but some did not. It is noteworthy that buried river channels are believed to be ubiquitous in Continental Shelf environments so the possibility of coincidental correlation is high.
(2) In ARE 2001, the spatial locations of the clutter features changed significantly as the long-range active sonar ship tracks varied. This gave the impression that the bistatic orientation of the scatterer may be a significant parameter in clutter physics. For example, clutter might appear as glints on a bending river channel that move along the channel as the source and receiver move. An analogy might be how glints on a curved shiny spoon move with viewing or lighting direction. However, due to the very limited time available for ARE 2001, it was not possible to accurately determine the purely temporal variations of the clutter.
(3) Large schools of fish were observed in the Strataform area during ARE 2001. Very dense clusterings of certain observed fish species, on the order of 1 fish per square meter, could also account for the observed active sonar clutter based on subsequent waveguide scatter modeling. Clutter from fish schools is expected to be both temporally and spatially variable.

More time was available in MAE 2003 to repeat tracks in the vicinity of previously charted river channels, where clutter features were found in ARE 2001. Near each major river channel feature, for example, the same two tracks were typically repeated for at least two days to study both the spatial and temporal evolution of the clutter. Movies were made at sea of the clutter evolution.

The findings were remarkable in that all clutter features in the vicinity of the river channels were observed to evolve both in time and in space. Clutter features were found to move throughout the survey area and sometimes cross known geologic features such as river channels. The clutter features were observed to cluster, disperse and gradually disappear and then emerge in the general vicinity at later times. As a result, they do not consistently correlate with static geologic features. The long-range active sonar data on its own shows that the primary source of clutter corresponds to targets moving in the waveguide. This was made certain by our ability to accurately register a number of fixed-point targets that we deployed as controls at various locations throughout the experiment.

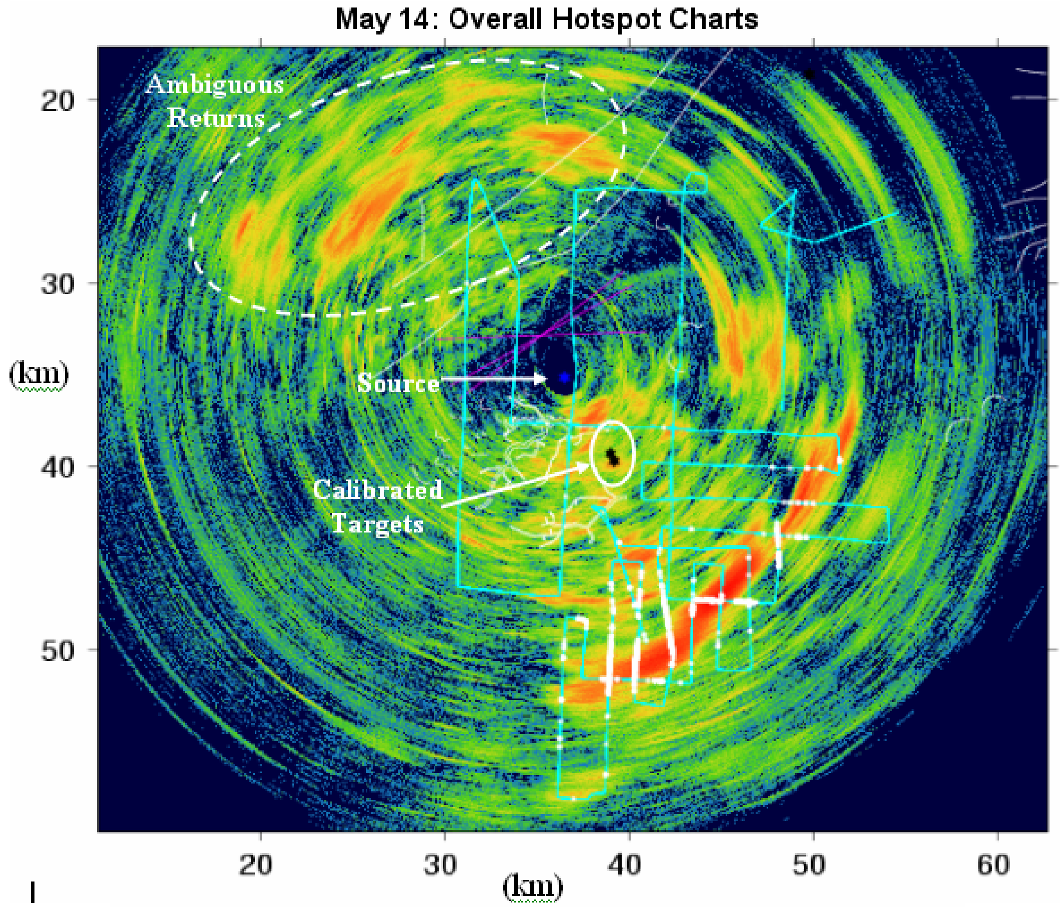
A thorough statistical analysis of ARE 2001 clutter data in regions where the sub-bottom geomorphology has been mapped shows that repeatable clutter does not favor buried river channel locations over non-river-channel locations [1]. One statistical investigation was conducted over the area within the yellow box of the figure below. The corresponding table shows that the frequency of occurrence of repeatable clutter within buried river channels has a mean between 3.7% and 4.9% and standard deviation between 1.8% and 4.3%. This standard deviation differs by less than a standard deviation from the area occupied by the channels in the subimage of 5.8%. This demonstrates that to within errors of statistical analysis, there is no significant difference between the frequency of occurrence per unit area of repeatable clutter events that chart within areas occupied by river channels and those that chart outside of areas occupied by river channels.

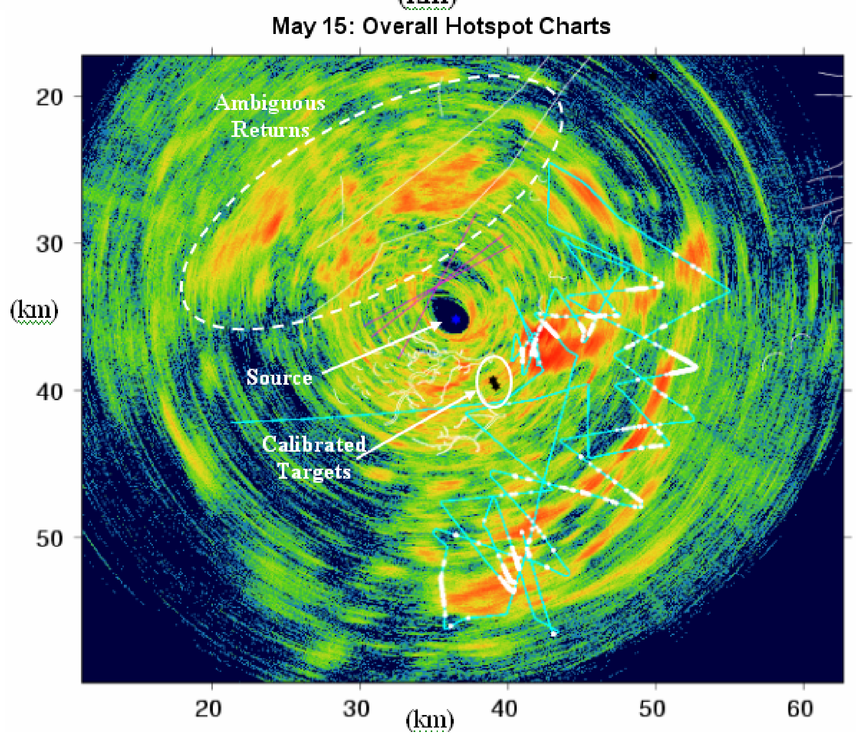



| Track Index, n | Track Name | $N_n$ | $P_n(10\%)$, % | $P_n(20\%)$, % |
|---|---|---|---|---|
| 1 | 13 | 46 | 3.2 | 12.0 |
| 2 | 14 | 46 | 2.0 | 0.0 |
| 3 | 17 | 49 | 4.4 | 3.2 |
| 4 | 18 | 47 | 4.9 | 10.8 |
| 5 | 19 | 9 | 9.3 | 8.2 |
| 6 | 20 | 9 | 4.9 | 3.4 |
| 7 | 23x | 15 | 8.5 | 10.1 |
| 8 | 91 | 60 | 4.2 | 2.6 |
| 9 | 91x | 42 | 3.2 | 3.3 |
| 10 | 92 | 94 | 4.5 | 0.0 |
| 11 | 93 | 74 | 1.2 | 0.5 |
| Unweighted Mean | $\overline{P} = \frac{1}{M}\sum_{n=1}^{M} P_n$ | | 4.6 | 4.9 |
| Unweighted Std. Dev. | $\sigma = \sqrt{\frac{1}{M}\sum_{n=1}^{M}(P_n - \overline{P})^2}$ | | 3.7 | 3.7 |
| Weighted Mean | $\overline{P'} = \frac{1}{\sum_{n=1}^{M} N_n}\sum_{n=1}^{M} N_n P_n$ | | 2.3 | 4.3 |
| Weighted Std. Dev. | $\sigma' = \sqrt{\frac{1}{\sum_{n=1}^{M} N_n}\sum_{n=1}^{M} N_n (P_n - \overline{P'})^2}$ | | 1.8 | 4.3 |

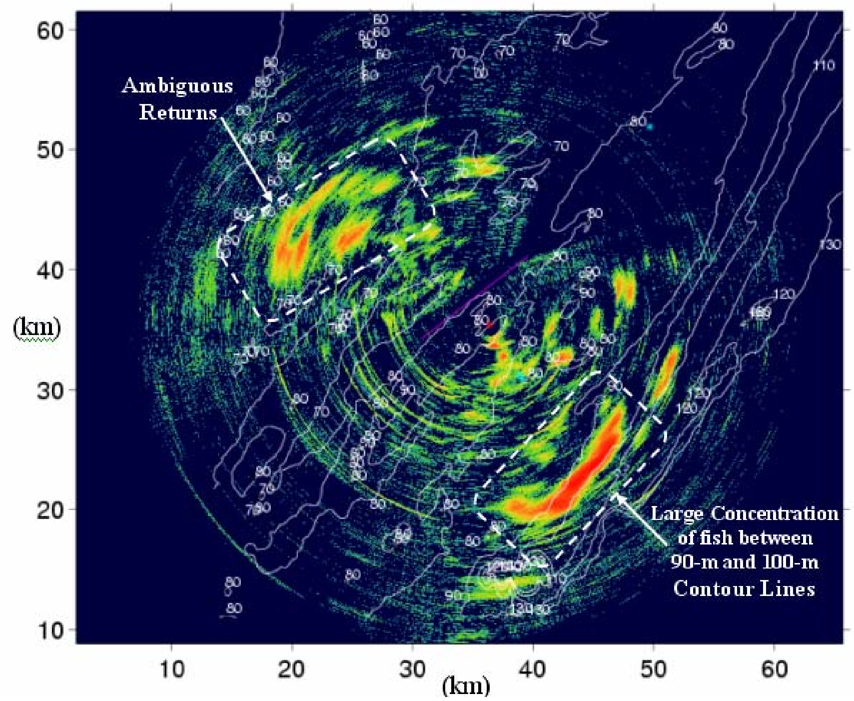
A full-field waveguide scattering model for fish was developed by the PI, and his post-doctoral fellow Purnima Ratilal, to investigate the coherent and incoherent scattering from schools of fish over long ranges in a stratified ocean waveguide. They found that scattering from large, densely-populated fish schools (on the order of one fish per square meter) at low frequencies can cause clutter that stands significantly above the reverberation background in both low and mid frequency active sonar systems [2, 12]. These theoretical results, as well as the presence of many clutter features that had no correspondence with surface or sub-bottom geomorphology in ARE 2001 prompted us to include fish surveys as an essential part of MAE 2003.

Over a period of roughly three weeks, high correlation was found between locations of prominent clutter detected by the active sonar system and locations of densely clustered fish schools measured with the fish-finding sonar. Many of these correlations were made with data obtained simultaneously within a roughly two-hour lag. In addition, regions absent of clutter were also found to be absent of significant fish populations. As an example, the following figures show fish-finding sonar tracks (cyan) and dense populations of fish (white dots), indicated by prominent returns from the fish-finding sonar, overlain onto overall hotspot charts:




Fish schools were observed to favor certain oceanographic fronts and bathymetric contours where food and nutrients are abundant, but were dynamic and often discrete and target-like in a given vicinity.




## IMPACT/APPLICATIONS

MAE 2003 demonstrated that discrete clutter events are consistently a major problem for active sonar operations in Continental Shelf environments, even those with little or no bathymetric relief. Preliminary findings show that the dominant source of clutter in the New Jersey Continental Shelf (STRATAFORM) is marine life, particularly fish schools. This is exhibited in massive schools of fish and smaller clusters of fish, moving and evolving with time.

## TRANSITIONS

The predominant cause of clutter in Navy sonar system in continental shelf environments may often be fish schools. Full-field waveguide models for acoustic reverberation and target scattering are needed to model acoustic clutter in continental shelf environments. Many US-Navy sponsored programs in active sonar beyond the ***basic research level*** have already gotten word of these ***basic research results*** through the widely distributed cruise summary of MAE 2003 that the PI sent to his ONR sponsor and have begun to include contributions from fish schools in their reverberation models. This rapid transition is a direct result of the findings of this ***basic research program***. Ideas and concepts transition faster than anything else.

## RELATED PROJECTS

Other organizations participating in the Geoclutter Program are UTIG, NRL, ARL-PSU, and NUWC.

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